Development of a Coincidence Measurement System for Scattered and Decay Particles Using a Streaming DAQ and Digitizers

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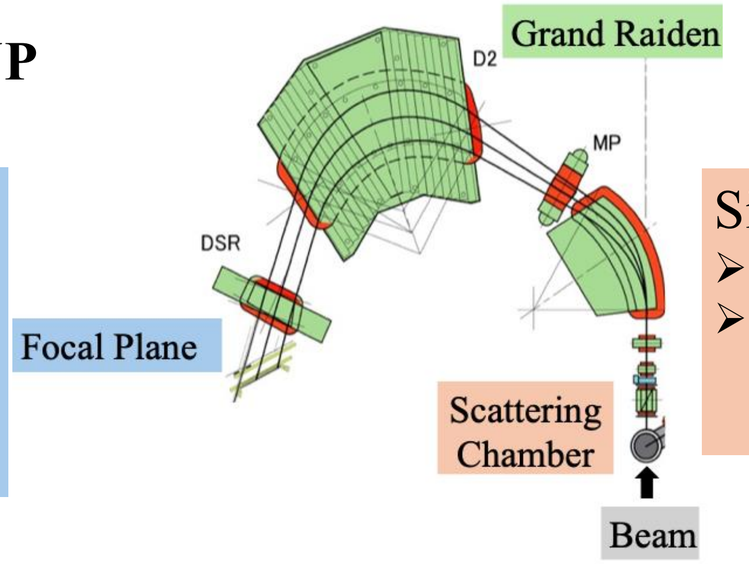
Introduction & Background

There is a strong demand to establish a **coincidence measurement system** combining the high-resolution spectrometer **Grand Raiden** with **waveform-acquisition digitizers** for silicon detectors. This technique is essential to determine excitation energies and perform **pulse shape analysis** of silicon detector signals for **low-energy particle identification (PID).** This achievement significantly **expands the experimental capabilities at RCNP.**

■Experimental @Grand Raiden at RCNP

Vertical Drift Chamber and Plastic Scintillator
- ➢ **Streaming DAQ**
- ➢ SPADI Alliance DAQ Package
  - ➢ AMANEQ (Streaming HR/LR TDC)
  - ➢ NestDAQ (Software Framework)
  - ➢ ARTEMIS (Analysis Framework)



Silicon Detector
- ➢ **Triggered DAQ**
- ➢ CAEN V1730SB (Waveform Digitizer)
  - ➢ DPP-ZLE Mode
  - ➢ 14-bit, 500MHz

Challenge: Cross-architecture event reconstruction

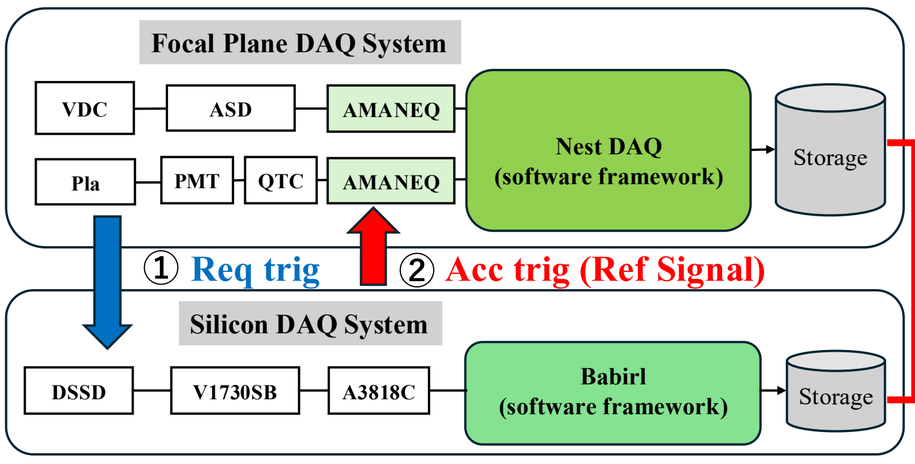
Streaming DAQ
(AMANEQ, NestDAQ, ARTEMIS)

Bridging the Gap

Triggered DAQ
(V1730SB, Babirl(RIBF DAQ))

Hardware & Software Implementation

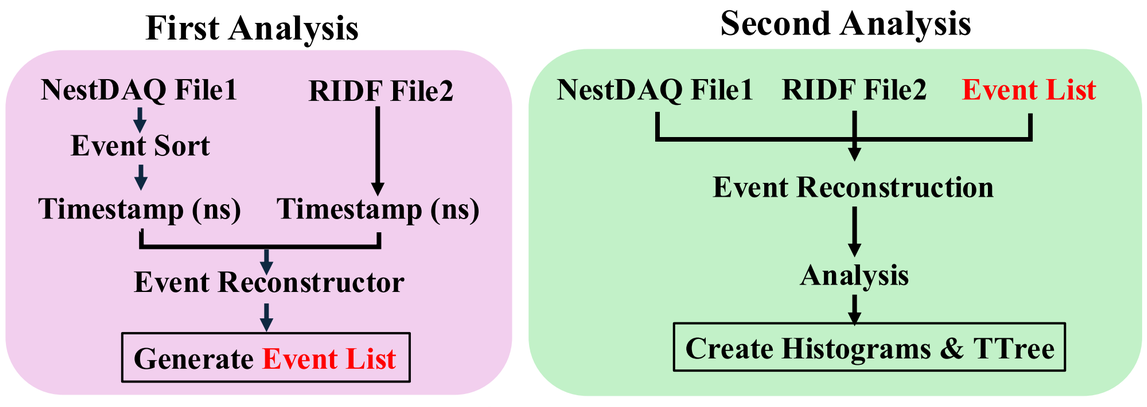
■ Hardware Architecture



Focal Plane DAQ: 125 MHz (AMANEQ MIKUMARI CLK)
Silicon DAQ: 125 MHz (V1730SB)

■ Software Development

ARTEMIS Flow



Event Reconstructor Algorithm

Initial Scan:
Scans timestamp combinations of the first 1000 events to locate the peak and set the baseline offset.

Window Judgement:
Checks if the drift-corrected difference falls within the coincidence window.

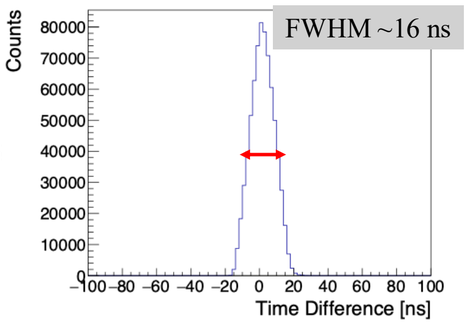
Drift Tracking:
Dynamically updates a moving average of recent offsets to absorb continuous clock drift over time.

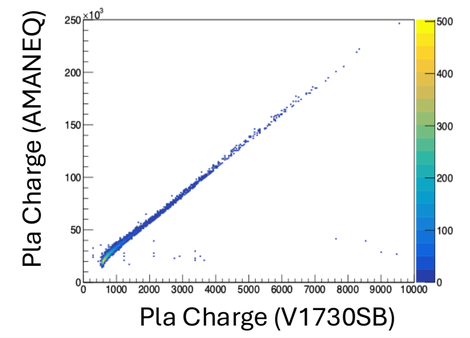
Performance Evaluation & Results

■ Timestamp Verification via Pulser
- Validated timestamp synchronization stability using a pulser signal across various trigger rates (500 Hz, 1 kHz, and 5 kHz).

■ Physical Correlation Check via Source
- ^{90}Sr source (trigger rate: ~830 Hz)
- Fed identical Pla signals into both AMANEQ and V1730SB
- Confirmed high-fidelity linear charge correlation

■ Reconstruction Efficiency
- Achieved a high event reconstruction efficiency of **95% — 98%**.





Future Outlook: On-FPGA Real-Time Signal Processing

■ Challenges in High-Rate Experiments

Bottleneck:
Data-transfer throughput becomes a critical bottleneck due to the massive volume of waveform data.

Solution:
Transition to a fully streaming Silicon DAQ system with **on-FPGA hardware acceleration**.

■ On-FPGA Processing & ELI-NP Collaboration:

Developing firmware for the CAEN VX2730 to implement a real-time digital triangle filter, processing waveforms on the hardware layer to extract and transmit only key PID features, energy, and timing for efficient data reduction.

$$y_i = \left(\sum_{k=1}^{L} x_{i+k}\right)/L - \left(\sum_{k=-L}^{-1} x_{i+k}\right)/L \quad L\text{: Filter length (20 is the optimum)}$$